versus its own customers. when facilities to serve such requests **are** not immediately available. Whether or not the Company's policies with *respect* to provisioning of DS1/DS3 UNE loops when facilities are nor mediately available would otherwise comply **with federal and** state **law,** that unequal and discriminatory conduct clearly violates the FCC's non-discriminatory standard for provision of UNEs. ***On*** thar basis. the Comssion should not find Verizon DC **to** comply with **Checklist** Items **4** and 5 until this situation is rectified.

33 Paragraphs 174-200 of the Checklist Declaration address Verizon's treatment of CLEC orders for DSI and DS3 UNE loops and interoffice **transport**. The Declaration notes that "Verizon DC offers access to unbundled high capacity loops. including DS-1s, **DS-3s** and other specially designed digital loops in the same manner **as** in Verizon ***NY,*** Verizon MA. Verizon NJ. and Verizon PA."[39] Relative to DS1/DS3 unbundled loops. the Checklist Declaration refers to the Verizon-wide policy set forth in a July 24. 2001 Verizon lener issued to CLECs on a Verizon-wide basis which has ken reproduced in Attachment 208 to the Checklist Declaration.[40] The lener states that:

39 Checklist Declaration. at para 171

40 *Id.*. at para 175 This lener was also posted on Venzon's website **as part** of its Verizon **East** wholesale services resources. and **was** accessible at http://128.11.40.241/east/wholesale resources clec_01 07_24.htm. Venzon does not cite to the **same** lener when discussing its DS1/DS3 unbundled IOF obligations (see *id.*, at para 198), but the lener refers to both loops and **IOF** and the policy clearly encompasses both types of facilities

> In compliance with its obligations under applicable law. Verizon will provide unbundled DS1 and DS3 facilities (loops or IOF) to requesting CLECs where existing facilities are currently available. Conversely, Verizon is not obligated to construct new Unbundled Network Elements where such network facilities have nor already been deployed for Verizon's use m providing service to its wholesale and retail customers.

The letter goes on to state the following:

> Moreover. although Verizon has no legal obligation to add DS1/DS3 electronics to available wire or fiber facilities to fill a CLEC order for an unbundled DS1/DS3 network element Verizon's practice is to fill CLEC orders for unbundled DSI/DS3 network elements as long as the central office common equipment and equipment at the end user's location necessary to create a DS1/DS3 facility can be accessed. *However. Verizon will reject an order for an unbundled DS1/DS3 network element where (i) it does nor have rhe common equipment in rhe cenrral office. at rhe end user's location, or outsidepiant facility needed to provide a DS1/DS3 network element. or (ii) there is no available wire or fiber facility between the central office and the end user*

This policy appears to lead to a significant number of orders that are rejected forreason of lack of available facilities. For example. Venzon admitted in its parallel Maryland Section 271 proceeding that it has denied some 13% of CLEC requests for DS1/DS3 orders for lack ofavailable facilities.[41]

41. Maryland PSC Case No 8921, Venzon-Maryland Response to Allegiance Telecom of Maryland Data Request No. 2-5 states thar "173 UNE DS1s out of 1330 requests (13%) have been rejected for no facilites [SIC] in Maryland from Jan '02 through June *'02."*

34. In stark contrast to its acknowledged policy of rejecting wholesale orders for unbundled DS1/DS3 loops for lack of available facilities, Verizon has admitted that it does not reject orders from its own retail customers when facilities are not available. Specifically, Verizon stated the following in response to a data request on this issue in its Section 271 review before the Rhode Island Public Utilities Commission:

> Verizon does not track the reason(s) why a retail or a wholesale order may be rejected (*e.g.*, due to a lack of facilities). ***As a general matter, retail orders are not rejected due to a lack of facilities because Verizon generally will undertake to construct the facilities required to provide service at tariffed rates (including any applicable special construction rates) if the required work is consistent with Verizon's current design practices and construction.*** Like its retail and carrier access customers, Verizon's CLEC customers may request Verizon to provide DS1 and DS3 services pursuant to the applicable state or federal tariffs.[42]

35. Verizon appears to believe that its preferential treatment of its own retail customers in circumstances when DS1/DS3 facilities are not immediately available is excusable, because CLECs can order comparable network elements from its "applicable state or federal tariffs", presumably referring to its special access tariffs. It is not. As demonstrated above, Verizon routinely acts to fulfill DS1/DS3 orders from its retail customers in the same circumstances in which it will reject DS1/DS3 orders from

42 Rhode Island PUC Docket 3363, Verizon Response to PUC-CON 1-12(a)-(c), emphasis supplied. This data response has been reproduced in Attachment 5 to my Affidavit. While Verizon made this response in a proceeding before the Rhode Island PUC, as I indicated above, Verizon has established its policy relative to DS1/DS3 facilities construction on a Verizon-wide basis, so that it applies to Verizon DC's services in the District as well.

its competitors. Even if a CLEC *can* eventually obtain a DS1/DS3 service under Verizon's special access tariff, the CLEC has suffered significant competitive disadvantage because: (1) the CLECs original service request has been denied; (2) it must enter a new service request, so that the "clock" **on** service fulfillment is restarted (meaning that the end user **is** subjected to additional delay of service); (3) the senice, when provided under the **special** access tariff, **will** be **subject** to different **terms** and conditions and different, higher charges than would otherwise apply to a UNE facility. In contrast, Verizon's retail customer **is** not required to obtain service from the **special** access tariffs and thus is insulated from these consequences. For a recourse to Verizon's special access tariffs not to constitute anti-competitive, discriminatory conduct, it would have *to* apply equally to the Company's own **retail** customers, as well as CLECs, in precisely the same conditions.[4]

Based on this evidence, the Comssion should find that Vernon's current provisioning policies and practices for DS1/DS3 network elements *are* discriminatory and anti-competitive, and should order the Company *to* change them. Specifically, the Comssion should require Venzon to cease rejecting **CLEC** orden for unbundled DS1/DS3 loops in cases when facilities are nor immediately available, and mead commit to fulfilling those service requests in precisely the same manner (including coordination with network construction plans), and within the same provisioning intervals, as the Company routinely applies to retail orders for DS1/DS3 loops. In order to monitor

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4 Of course, end users will be bener served if service requests from neither CLECs nor Verizon's retail customers are rejected due to lack of facilities and instead provisioning in those cases is coordinated with facilities construction in the same, non-discriminatory manner for both types of **orders.**

Venzon's performance in this regard the Commission should also order the Company to track all orders (separately for retail versus wholesale) for DS1/DS3 network elements for which facilities are initially not available, recording (1) the date on which the determination that facilities are not available was mad:. (2) the specific remedy proposed by the Company, including new construction triggered by or coordinated with the service request. (3) the revised due date for service installation, and (4) the actual dare on which service is initiated. Until these steps have been taken and there is a clear demonstration that Verizon DC has rectified this situation, the Commission should not find Venzon DC to comply with Checklist Items 4 and 5. Implementing this recommendation will help to ensure that CLECs are truly afforded a "meaningful opportunity to compete" in the District's marketplace for digital DSI DS3 services

CONCLUSION AND RECOMMENDATIONS

37. For the reasons set forth in detail in this affidavit, I recommend that the Commission withhold approval of Venzon DC's request for a Commission finding that it is in full compliance with the Section 271(c)(2)(B) checklist until the following additional *steps* have been taken:

Checklist Item 2 Venzon DC's currently-applied "interim" UNE rates are more than five years old and fail to take mto account the declining *cost* trends that Venzon DC has experienced over that time Thus, those rates are not TELRIC-compliant and pose a barrier to competitive entry Before finding Venzon DC to comply with Checklist Item 2 the Comssion must establish permanent. cost-based. UNE rates for Venzon DC thar are compliant with the FCC-prescribed TELRIC methodology

Checklist Item *2* The Company should affirmatively demonstrate that its ExpressTRAK OSS *system* is functioning with a minimum of errors and is rendering wholesale bills in an accurate manner in the District In addition, the Commission should work with Venzon DC and other interested parties to devise alternative metrics for wholesale billing performance to ensure that CLECs obtain timely and accurate wholesale bills in the future

Checklist Item 4 The Comssion should require Venzon DC to submit PR-2 and

PR-3 memc data for more recent months that affirmatively demonstrates that Verizon DC s d a t i o n performance for non-dispatched orders of 1-5 lines is not discriminating against CLECs in favor of its own retail customers

Checklist Items 4 and 5: Verizon DC should be required to amend in the manner described above. its construction policy and practices for the provisioning of DS1/DS3 unbundled loops and interoffice transport when facilities are not immediately available. so that it no longer discriminates against CLECs in favor of its retail customers The Commission should not find Venzon DC to comply with Checklist Items 4 and 5 until monitoring is in place and there has been a clear demonstration that Verizon DC has rectified this situation.

This concludes my affidavit

Before the

PUBLIC SERVICE COMMISSION
OF THE DISTRICT OF COLUMBIA

In the Matter of Verizon Washington. D C Inc s Compliance With the Conditions Established in Section 271 of the Federal Telecommunications Act of 1996	**Formal Case No. 1011**

COMMONWEALTH OF MASSACHUSETTS)
) ss
COUNTY OF SUFFOLK)

AFFIDAVIT OF SCOTT C. LUNDQUIST

SCOTT C LUNDQUIST, of lawful age, certifies as follows:

I am Vice President of Economics and Technology (ETI), Two Center Plaza, Suite [illegible] Boston, Massachusetts 02108. I am authorized to verify the statements contained in **the** foregoing Affidavit prepared by me on behalf of the Office of People's Counsel of the District of Columbia.

The foregoing Affidavit identified as OPC Exhibit B in FC 1011 was prepared [illegible] upon my review of the testimony being proffered by Verizon Washington. **D.C** in **support** [illegible] Application for authority, pursuant to Section 271 of the *Telecommunications Act of 1996* [illegible] ("Act"), to enter the in-region long distance market in the District of Columbia, and [illegible] other pertinent documents

I certify that the foregoing statements made by me are true and correct to the best of my knowledge, information and belief. I am aware that if any of the foregoing statements made by me are willfully false, I am subject to punishment

Scott C. Lundquist

Subscribed and sworn to before me this 27 day of September, 2002

Notary Public

My commission expires 3/3/06

Attachment 1

Statement of Qualifications

SCOTT C. LUNDQUIST

Scon C. Lundquist is a Vice President at ETI, where he performs strategic and regulatory analysis. project management and client support services for ETI's consulting projects in telecommunications regulation and economics. Since joining ETI in 1986. Mr. Lundquist has conmbuted to a broad range of telecommunications consulting projects. including work in the areas of costing and interconnection. implementation of competition policies. alternative regulation. network modernization and productivity, and rate design. *Mr.* Lundquist holds a B.A. from Harvard College in Psychology and *Social* Relations.

Mr Lundquist has managed or participated m over seventy major projects concerning tariff and/or cost analysis. rate design and regulatory policy development. His work has included direct consulting suppon to regulatory commissions m the U.S., Canada. China. and the Philippines. as well as service to telecommunications users groups and competitive suppliers. Mr. Lundqun has testified as an expen witness on telecommunications matters in Alabama Califorma Connecticut. Hawaii, Nevada. New Jersey, Ohio, Texas, and Washington *state.* He has also assisted m the development of expen testimony submitted in over forty contested regulatory proceedings in a dozen states and Canada.

Mr Lundquist spent nine weeks in Beijing in 1994 working in close association with officials of the China Ministry of Posts and Telecommunications on a technical assistance project sponsored by the Asian Development Bank. Mr. Lundquist developed and conducted several seminars for senior MPT officials on interconnection, tariffing and rate design for non-basic services. and regulatory restructuring issues. Mr. Lundquist was also the Project Manager io: ETI's 1993-1994 engagement by the National Telecommunications Commission of the Philippines. In the course of this assignment. Mr. Lundquist spent six months on-site in Manila conducting several institutional strengthening activities. including assistance in implementing new competition and interconnection policies and staff training in regulatory methods.

Mr Lundquist's receni work has focused on the implementation of local service competition policies and interconnection arrangements between incumbent local exchange carriers (ILECs) *and* new marker entrants. in these assignments. Mr. Lundquist has offered expen testimony on behalf of consumer advocates and new entrants concerning ILEC cost studies for unbundled network elements (UNEs) in California. Hawaii. Ohio. Nevada, and New Jersey (1997-2001); testified on behalf of new entrants in California arbitration proceedings concerning interconnection costs and pricing (1996. 1999); and analyzed ILECs' proposed local number portability (LNP) costs and prices in the FCC's LNP investigation (1999).

Mr Lundquist has also continued to participate in cases involving other important regulatory issues. including ILEC merger proposals. rate design. alternative regulation plans, and ILEC applications for mer-LATA services authority under Section 271 of the federal Telecommunications Aci Mr. Lundquist directed ETI's research effon to support the American Association for Retired Person (AARP) study of the impacts of the SBC/Pacific Telesis and Bell Atlantic/NYNEX mergers (1999). and also contributed research and writing to ETI testimony and affidavits addressing the proposed Bell Atlantic/GTE merger (1999). In 1998, Mr. Lundquist testified of behalf of the Texas Office of Public Utility Counsel in Southwestern Bell's rate group reclassification case (1998). and co-managed ETI's consulting support to the Colorado Office of Consumer Counsel in US West's alternative regulation case (1998). In 1999, Mr. Lundquist provided consulting support to the staff of *the* Washington Utilities and Transportation Commission in a case involving US West's yellow pages operations and assisted the Arizona Residential Utility Consumer Office in their review of US West's application concerning Section 271 authority in Arizona. Most recently, Mr. Lundquist co-authored a comprehensive report on alternative regulation for US West that was sponsored by the Utah Division of Public Utilities, and testified in *Alabama* concerning BellSouth=s proposed rates and costs for Operations Support Systems (OSS) interfaces.

Mr. Lundquist has formerly served as Senior Consultant, Consultant, Senior Analyst, and Analyst at ETI. Prior to joining ETI, Mr. Lundquist performed computational and analytic work for research effons in both the Division of Applied Science and Psychology Department at Harvard University.

Major reports and papers on telecommunications authored by Mr. Lundquist include:

"Efficient Inter-Carrier Compensation Mechanisms for the Emerging Competitive Environment" (with Lee L. Selwyn), August 2001.

"Price Cap Plan for USWC: Establishing Appropriate Price and Service Quality Incentives in Utah" (with Pamcia D. Kravtin and Susan M. Baldwin). Prepared for the Utah Division of Public Utilities, March 2000.

"Bringing Broadband to Rural America: Investment and Innovation in the *Wake* of the Telecom Act" (with Lee L. Selwyn and Scott A. Coleman,. Prepared for AT&T, September 1999.

"Promises and Realities: *An* Examination of the Post-Merger Performance of the SBC/Pacific Telesis and hell Atlantic/NYNEX Companies" (with Scon A. Coleman). Prepared for the AARP Public Policy Institute, July 1999.

"Report on the RRD Investigation of Foreign Currency Adjustment Mechanisms". Prepared for the Philippines National Telecommurucations Commission, August 1994.

"Manual of Procedures for the Rates Regulation Division" (with Paul S. Keller). Prepared for the Philippines National Telecommurucations Commission, August 1994.

"Access Charges Implementation Strategy and Action Plan" (with the NTC Access Charges Research Group). Prepared for the Philippines National Telecommunications Commission, July 1994.

"RRD Operations Review" (with Daniel Espitia G.). Prepared for the Philippines National Telecommunications Commission, July 1994.

"Review of Annual Reporting Requirements for Telecommunications Common Carriers." Prepared for the Philippines National Telecommunications Commission, October 1993.

"The Infrastructure Dilemma: Matching Market Realities and Policy Goals" (with W.P. Montgomery). Prepared for the International Communications Association January 1993.

"A Roadmap to the Information Age: Defining a Rational Telecommunications Plan for Connecticut" (with Susan M. Baldwin et al). Prepared for the Connecticut Office of Consumer Counsel. October 1992.

"New Connections for the 1990s: Managing the Changing Relationship Between Corporate Telecommunications Users and the Local Telephone Company" (with W. Page Montgomery). Prepared for the International Communications Association, April 1990.

"Adapting Telecom Regulation to Industry Change" (with Dr. Lee L. Selwyn). Prepared for the International Communications Association and published in *IEEE Communications Magazine*, January 1989.

"A Study of Rate of Return Regulation and Alternatives - An Examination of Applicability to regulation of Telephone Companies by the Canadian Radio-Television and Telecommunications Commission" (with W. Page Montgomery and Lee L. Selwyn). Prepared for the Canadian Radio-Television and Telecommunications Commission March 1989.

"Telecommunications Competition in Michigan and Regulatory Alternatives: Market Structure and Competition in the Michigan Telecommunications Industry" (with Lee L. Selwyn. David N. Townsend. Patricia D. Kravtin). Prepared for the Michigan Divestiture Research Fund Board. April 1988.

Attachment 2

"Verizon introduces Voice Transmission Over Packet Switching Provided by Nortel Networks," Verizon News Release, July 2, 2002

News Release

Verizon Introduces Voice Transmission Over Packet Switching Provided by Nortel Networks

Initial Deployment Enhances Reliability and Capacity For Customers While Posirioning Verizon Network for Advanced Services

July 2, 2002

Media contact:
Mark Marcnand. Vernon. **518-396-1080**
Carrie McGranahan. Nonel Networks. **212-3174252**

NEW YORK -- Vernon (NYSE: VZ) has introduced packet switching to transmit voice phone calls with the successful deployment of Nortel Networks' (NYSE/TSX: NT) packet-switching equipment in large Vernon switching centers in New Jersey and Flonda

The move is pan of Vernon's overall effort to deploy the industry's most advanced technology in its nationwide network, continually improving service ana positioning the company's network to provide integrated voice and aata services

The deployments -- Verizon's first Step toward widespread deployment of packet-switching tecnnology in its voice network -- represent the largest application of packet-switching tecnnology for voice transmission by a local exchange Carrier in North America Thus far. tne New Jersey packet-switching deployment has successfully completed over 18 million voice phone calls

The deployments designed to evaluate the reliability of packet tecnnology. pave tne way for the expanded use of packet-switching technology for future voice transmission needs The lecnnology is designed to provide Verizon with faster call routing. greatly expanded network capacity and tne ability to deliver new services. while enabling a seamless transition for Verizon customers

This use of tne packet-switching tecnnology to carry voice calls is known as voice trunking over ATM switches or VToA ATM stands for Asynchronous Transfer Mode a high performance. cell-oriented switching ann multiplexing tecnnology historically used for aata applications

"Packet-switching technology will enable Verizon to provide customers with all the nigh quality services tney nave today. and realize efficiencies which do not exist in today's circuit-switching ennronment" said Phil narrington Verizon's VToA program manager "It is very important to us tnat this network transition be absolutely seamless to our customers and that it enable the delivery of mission-critical services with very high reliability We're also planning to deploy this technology at a number of new locations over tne nen 18 months"

"With this deployment Verizon is in an excellent position to efficiently accommodate growth ana build the foundation tor me delivery of new voice data and video services in the future," said Sue Spradley. president voice over Internet Protocol (VoIP) for Nonel Networks "Nortel Networks is in a umoue position to effectively enable this migration because of our detailed understanding of network design ana service delivery. our solid circuit-to-packet migration strategy. and our comprehensive voice over IP portfolio

Packet switching permits groups of messages -- voce or data -- from many different sources to snare Me same communications line, resulting in more efficient use of existing transmission capacity and lines. This provides a significant advantage over circuit switching --the technology used in telecommunications networks today -- which uses communications lines mat are dedicated to the same source and destination. Another advantage of Packet switching over circuit switching is mat it more readily lends itself to a distributed network, which is a more survivable network infrastructure in me event of damage to the network

Dunng the initial Venzon VToA deployment, voice calls are Being transmitted through major regional call- and data-switching centers known as tandems The two Vernon tandems are located m Newark, N.J., and Tampa, Fla

Tne two switching centers used products from Nortel Networks VoIP portfolio including me Succession* Communication Server 2000 softswitches Succession Multi-service Gateway 4000 and Passport* 15000 Multiservice Switches for ATM transport

VToA technology also offers me potential for a cost-effective way to migrate to a Voice over IP platform if the market and future technology justify that move at some time in me future

Venzon Communicabons (NYSE VZ) is one of Me world's leading providers of communications services Vernon is the largest phone company in the United Stales and the natron's largest wireless company with 133 8 million access line equivalents and approximately 29.6 million wireless customers Venzon is also the largest directory publisher in the world With more than S67 billion in annual revenues and nearly 248.000 employees Vernon s global presence extends to more than 40 countries in the Amencas Europe Asia and the Pacific For more information on Verizon visit http //www verizon com/

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Nonel Networks is an industry leader and innovator focused on transforming now tne world communicates ana excnanges information The company is supplying its service provider and enterprise customers with communications tecnnology ana infrastructure to enable value-added IP aata voice and multimedia services soanning Metro Networks Wireless Networks and Optical Long Haul Networks As a global company Nonel Networks does business in more than 150 countnes More information about Nonel Networks can Be found on me Web at www nortelnetworks com

*Nortel Networks Succession and Passpon are trademarks of Nonel Networks

Cenain information included in this Dress release is forward-looking and is subject to important risks ana uncertainties The results or events predicted in these statements may differ matenally from actual results or events Factors which could cause results or events to diner from current expectations include among other things the seventy and duration of the industry adjustment the sufficiency of our restructuring activities, including me potential for higher actual costs to be rncurred in connection with restructunng actions compared to the estimated costs of such actions, fluctuations in ooerafing results and general industry. economic and market conditions and growth rates, the abrlrty to recruit and retain qualified employees fluctuations in cash flow, the level of outstanding debt and debt ratings the ability to meet financial covenants contained in our credit agreements' the ability to make acquisitions and/or integrate the operations and technologies of acquired businesses in an effective manner the impact of rapid technological and markal change; the impact of price ana product competition international growth and global economic conditions particularly in emerging markets and including interest rare and currency exchange rate fluctuations: the impact of rationalization in the telecommunications industry the dependence on new product development tne uncertainties of the Internet: the impact of the credit risks of our customers and the impact of increased provision of customer financing and commitments. stock market volatility; the entrance into en increased number of supply turnkey and outsourcing contracts which contain delivery installation. and performance provisions. which. if no! met. could result in the payment of substantial penalties or liquidated damages; the ability to obtain timely, adequate and reasonably priced component parts from suppliers and internal manufacturing capacity; the future success of our strategic alliances: and me adverse resolution of litigation. For additional information with respect to certain of these and other factors see me reports filed by Nortel Networks with me United States Sewnties and Exchange Commission. Unless otherwise required by applicable securities laws. Nortel Networks disclaims any intention or obligation to update or revise any forward-looking statements, whether as a result of new information. future events or otherwise.

Attachment 3

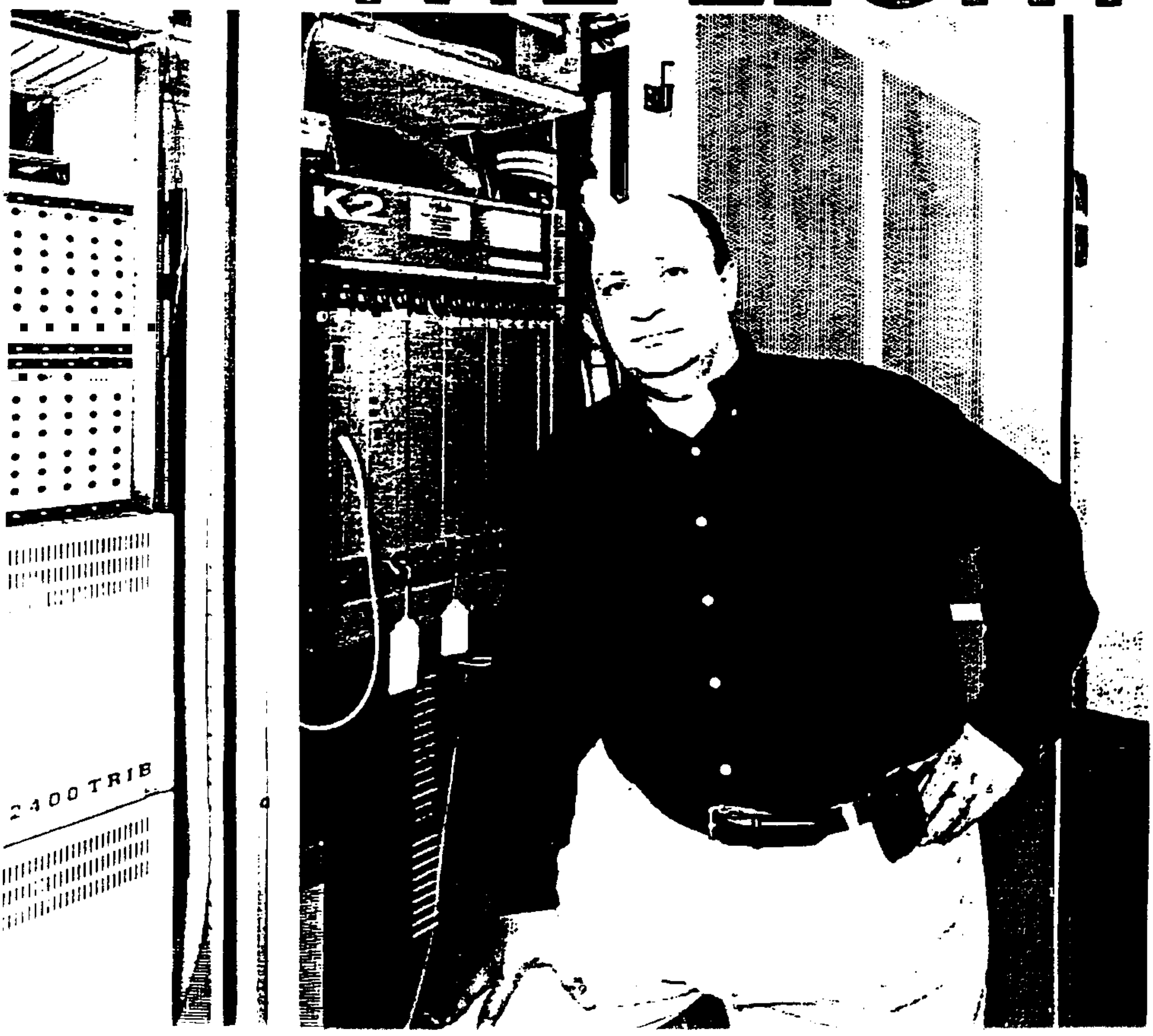
“The Triumph of the Light”

Scientific American

January 2001

by **Gary Stix,** *staff writer*

TRIUMPH OF THE LIGHT

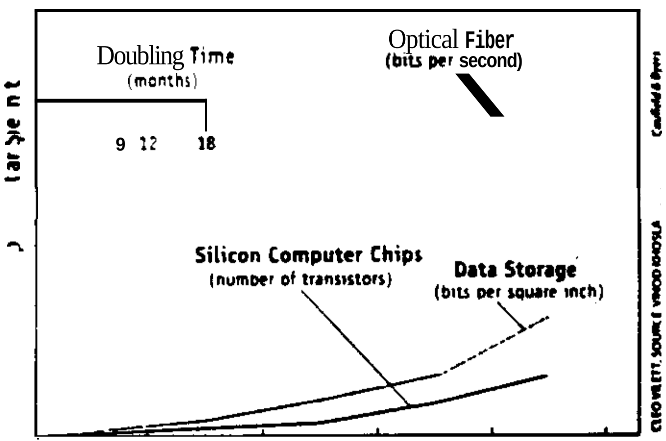


aror' clarity of a phone connection. Fiber links can channel hundreds of thousands of times the bandwidth of microwave transmitters or satellites, the nearest competitors for long-distance communications. As one wag pointed out, the only other technology that comes close to matching this delivery capacity ... full of videos

however

More imme

from



parco with 51.5 billion ior all of 1999, although this pace may have slowed in recent months. Tne success of a stock like component supplier JDS Uniphase stems in part from rne perception that its edge in integrated pnoronics could make it the nexr Intel.

Investment in optical communications already yields payoffs, if fiber optics is matched against conventional electronics. The cost of transmitting a bit of information optically halves every nine months, as against 1b months to achieve the same cost reduction io; an integrated circuit (the latter metric is famous as Moore's law. "Because or dramatic advances in the capacity and ubiquity of fiber-optic systems and subsystems. bandwidth will become roo cheap to meter," predicts A. Arun Sctravali, president of Lucent Technologies's Bell Laboratories in a reien: issue of *Bell Labs Technical Journal*.

Identica forecasts about a free resource eventually came to haunt the nuclear power industry. And rhc future of broadband networking, in which a full-length feature film would hc rransmitted as readily as an e-mail message, is still not a sure bet. A decade ago telecommunications providers and media companies started preparing tor rhe digital ... entertainment and ... hundred channels ... We're still waiting. ... the Internet, once viewed as ... for the government and schoolkids. has transmuted into the network that ate the world. E-mails and Web sites have rriurnphed over Mel Gibson and Cary **Grant.**

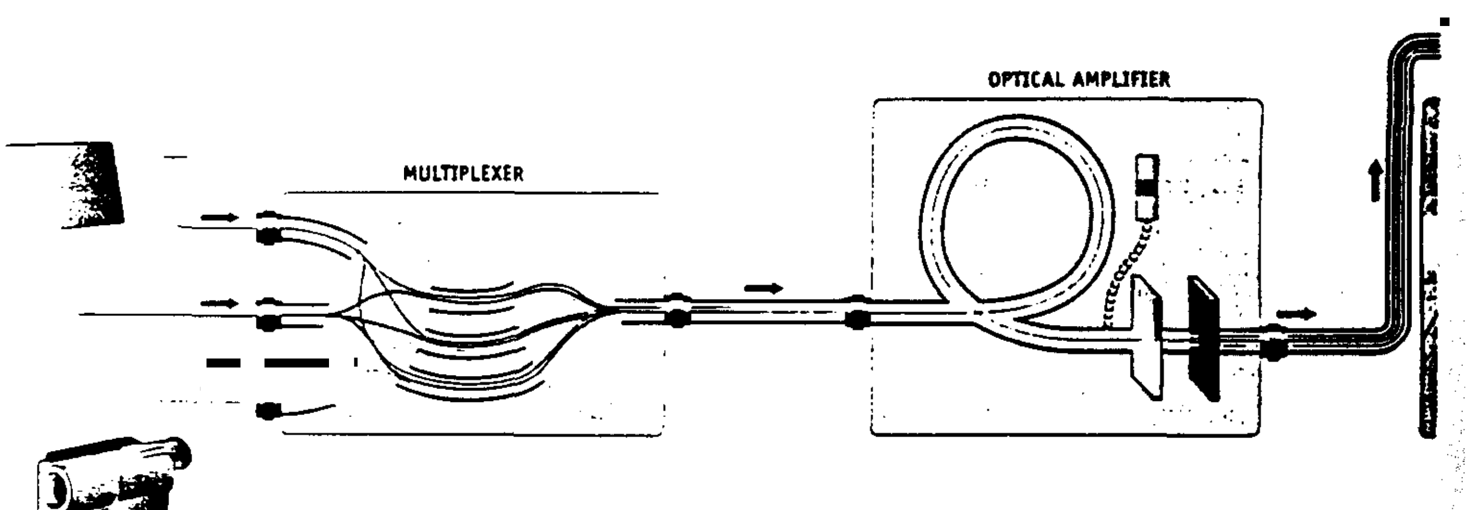
And Then There Was Light

Prospects of limitless bandwidth—the basis for speculations about networked virtual reality and high-definition videos—arc of relatively recent vintage. AT&T and **GTE** deployed the first optical fibers in the commercial communications network in 1977, during the hevday *of the minicomputer* and *the infancy* of the personal computer. A fiber **consists of a glass core and a surrounding** layer called the cladding. The core and cladding havc carefully chosen indices of refraction (a measure of the material's ability to bend light by certain amounts) to ensure thar the photons propagating in the core arc always reflected at the interface of the cladding. The only way the light can enter and escape is through the ends of the fiber. To understand the phvsics behind how a fiber works. imagine looking into a still pool of water. If you look straight down, you see the bottom. At viewing angles close to the water, all that is perceived is reflected light. A transmitter—either a light-emitting diodr or a laser—sends electronic data tnat have been converted to photons over the fiber at a wavelength of between 1,200 and 1,600 nanometers.

Today some fibers arc pure enough that a light signal can travel for abour **80 kilometers** without the need for amplification. Bur at some point the signal still needs to be boosted. The next significant step on rhc road ro the all-optical network came in the early 1990s, a time when the technology made artounding advances. It was then rha~ electronics for amplifying signals were replaced by stretches of fiber infused with ions of the rare-earth element erbium. When these erbium-doped fibers were zapped by a pump laser, the excited ions could revive a fading signal. The amplifiers became much more than plumbing fixtures for lighr pipes. They restore a signal without any optical-to-electronic conversion and can do so for very high speed signals sending tens of gigabits a second. Perhaps most important, however. they can boost the power of many wavelengths simultaneously.

This ability to channel multiple wavelengths enabled the development of a technology that has helped drive the frenzy of activity for optical-networking companies in the financial markets. Once *you* can boost the strength of multiple wavelengths, the next thing you want to do is jam as manv wavelengths as possible down a fiber, with a wavelength carrying as much dara as possihlc. The technology thar does this has a name—dense wavelength division multiplexing (DWDM)—that is a paragon of technospeak.

DWDM set off a handwidrh explo-



... NETWORKS will combine. amplify. switch and restore optical signals without convening them to an electronic transmission for processing. A dense wavelength division multiplexer (DWDM) will take different wavelengths of light and place them on a single fiber connemon. An optical amplision. With the multiplexing technology, the capacity *of* the fiber expands **by the** number of wavelengths. each of which can carry more dara rhan could be handied previously by a single fiber. Nowdays it is possible to scnc 160 frequencies simultaneously, supplying a total bandwidth of 400 gigabits a second **over** a fiber. Every maior telecommunications carrier has deployed DWDM, expanding rnc capacity of rhe fiber **that** is in the ground and spending what could bc less than half of what it **would** cost to lay new cable, while the equipment **gets** installed in **a** traction of rhe time it takes to dig a hole.

In rhc laboratory, meanwhile, experiments point toward using much of the capacity of fiber—dozens of individual wavelengths, each modulated **at 40** gigabits or more **a** second. for effective transmission rare of a **few** terabits a second. (One company, Enkido, has already deployed commercial links containing 40-gigabit-a-second wavelengths.) The engorgement of fiber capacity will nor **stop** anytime soon and could reach as high as 300 or 400 terabits a second—and, with new technical advances, perhaps exceed the petabit barrier.

The telecommunications **network**, however, [illegible] consist of links that tie together point [illegible] ... and point B—switches are needed to route the digital flow to its ultimate destination. The enormous bit [illegible] laboratory [illegible] light streams are roured using conventional electronic switches. Doing so would **require a** multiterabit signal to be convened into dozens or hundreds of **lower-speed** electronic signals. Finally. switched signals would hare **to** be reconvened to photons and reaggregated into light channels that are then sent **our** through a designated output fiber.

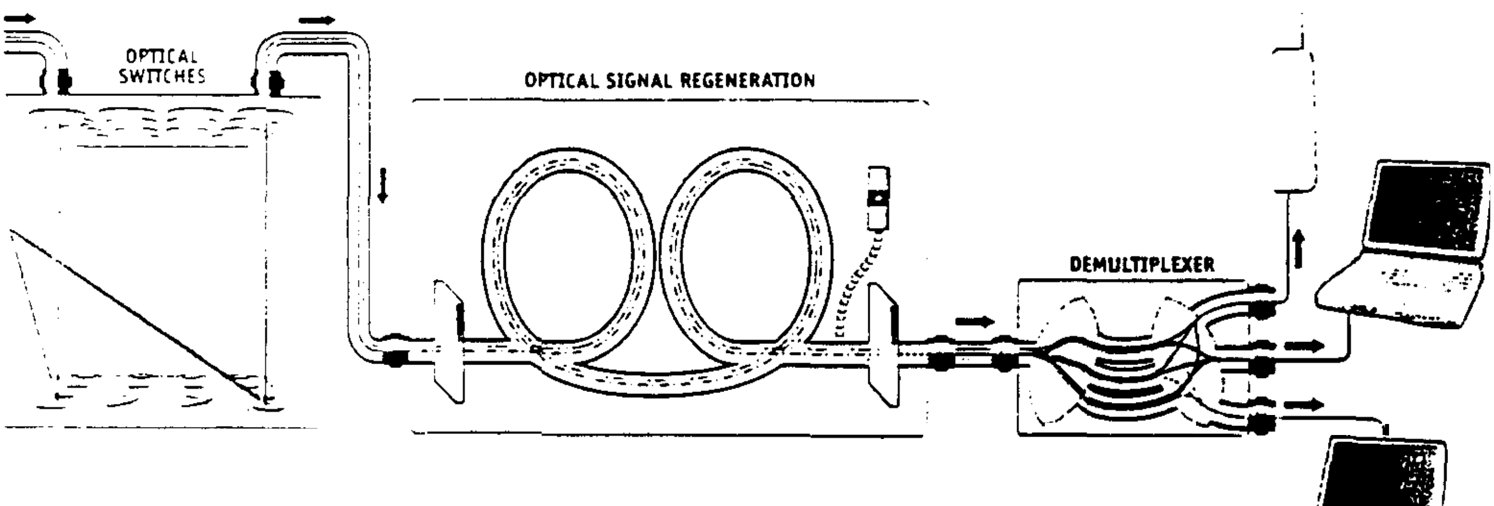
The cost and complexity of electronic switching have prompted **a mad** scramble to find a means of redirecting either individual wavelengths or the entire light signal in a fiber from one pathway **to** another without the optoelectronic **conversion**. Research teams. **often** inhabiting tiny start-ups, fiddle with microscopic mirrors. liquid crystals and fan lasers **to try** to **devise** all-optical switches (see "The Rise of Optical Switching," on page 88).

All-optical switching, however. will difier in iundamcntal ways **from** existing networks that switch individual chunks of data bits. such as IP (Internet Protocoli packers. Ir is an easy **task** for the electronics in routers **or** large-scale telephone switches **to** read on a packer the address thar denotes its destination. Photonic processors. which arc at about the **same** stage of development thar electronics was in the 1960s, **have** demonstrated the ability to read a packet only in laboratory experiments.

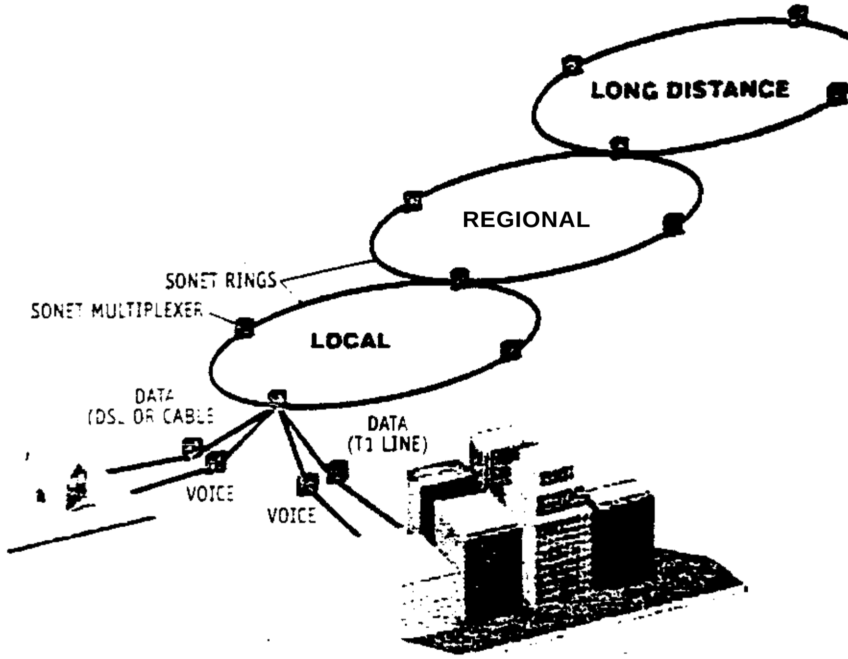
Optical switches heading to rhc marketplace hark **back** to earlier generations of electronic equipment. They will switch a circuit—a **wavelength** or an entire fiber—from **one** pathway to another, leaving **the data-carrying** packets in a **signal** untouched. *An* electronic signal will *set* the switch in the right position so **that** ir directs an incoming fiber—or wavelengths within that fiber—to a given output **fiber.** But none of **the wavelengths** will be **converted** m electrons ior processing.

Optical circuit switching may be only an interim **step. however. As** networks get faster, communications companies may demand nha: could become the crowning touch tor all-optical network**ing,** the switching of individual packets using optical processors (see "Routing Packets with Light," **on** page 96).

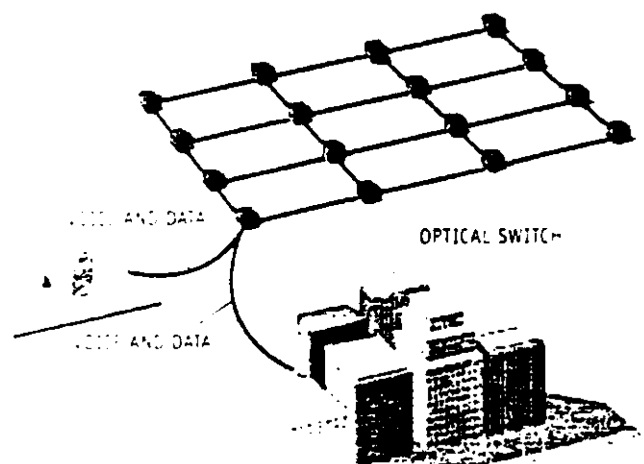
With the advent *of* optical packer switching, individual packets will **still need** to **get** read and routed at the edges of optical networks—on local phone networks near the points where they arc sent or received. **For** the moment, that task will still fall to **electronic** routers **from** companies such **as** Cisco Systems. Even so, the **evolution** of optical networking will promote changes in the way networks are designed. Optical switching may eventually make obsolete existing lightwave technologies bared on the ubiquitous **SONET** (Synchronous Optical Network) communications standard. which relies on electronics for conversion and **processing of** individual packets. And this may **proceed** in tandem with the gradual withering away of Asynchronous Transfer Mode



[illegible]ner will boost the signals. An optical switch will route different wavelengths, and **an** amplifier **that** regenerates a signal will restore the timing and shape of the pukes in the signal before a demultiplexer separates each wavelength and sends telephone calk computer files or video to their recipients.



... maintain mostly separate electronic connections for voice and data and achieve reliability using rings based on the Synchronous Optical Network (SONET) communications standard: if one link is cut, traffic flows down the other half of the ring. The SONET multiplexer aggregates traffic onto the ring.



... will channel all traffic over the same fiber connection and will provide redundancy ... the Internet's mesh of interlocking pathways: when a line breaks, traffic can flow down several alternating pathways. Optical switching will become the foundation ... these integrated networks.

ATM, another phone company standard for packaging information.

In this new world, any type of traffic, whether voice, video or data, may travel as IP packets. A development heralded by telecommunications for at least 20 years—the full integration of voice, video and data services—will be complete. "It's going to be a data network, and everything else, whether it's voice or video, will be applications traveling over that data network," says Robert W. Lucky, a longtime observer of the telecommunications scene and director of research for the technology development firm Telcordia.

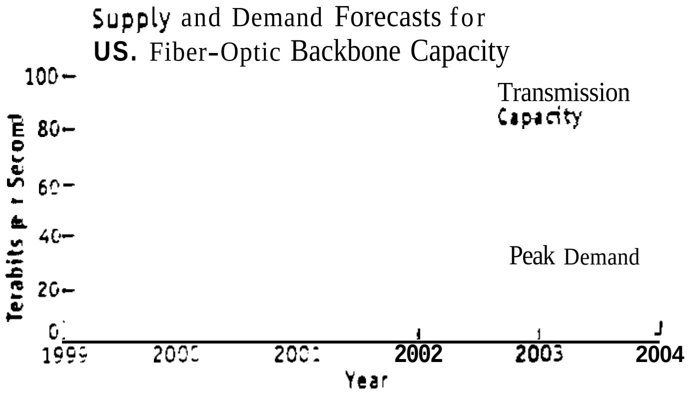
When you ring home on Mother's Day, the call may get transmitted as IP packets that move on a Gigabit Ethernet, a made-for-the-superhighway version of the ubiquitous local-area network (LAN). Gigabit Ethernet would in turn ride on wavelength-multiplexed fiber. Critics of this approach question whether such a network would provide ATM and SONET's quality of service and their ability to reroute connections automatically when a fiber link is cut.

Life would be simpler, though. The phone network would become just one big LAN. You could simply slot an Ethernet card into a computer, telephone or television, a far cheaper and less time-consuming solution than installing new SONET hardware connections. Some companies are even now preparing for the day when IP reigns. Level 3 Communications, a carrier based in Denver, has laid an international fiber network stretching more than 20,000 miles in both the U.S. and overseas. Although the network still relies on SONET, CEO James Q. Crowe foresees a day when these costly legacies of the voice network will wither into nothingness. "It will be IP over Ethernet over optics," Crowe says.

Home Light Pipes

Even if network engineers can pare down the stack of protocols that weighs heavy on today's network, they must still contend with the need to address the "last mile" problem, getting fiber from the curbside utility box into the TV room and home office. Some builders now lay out new housing projects with fiber, presaging the day when households routinely get their own wavelength connection. But cost still hangs over any discussion of fiber to the home. Until recently, advanced optical-networking equipment, such as DWDM, was too expensive to consider for deployment on regional phone networks. Extending the equipment into a wall panel of a split level—at perhaps $1,500 a line—still costs more than all but a few are willing to pay. Most people have yet to take delivery of their first megabit connection. So it remains unclear when the time will come when the average household will need the gigabits to project themselves holographically into a neighbor's house rather than just picking up the phone.

Dousing "Help me, Obi-Wan Kenobi" fantasies, engineers are confronting an array of nettlesome technical problems before a seamless all-optical network can become commonplace. Take one example: even with lightwave switching in



FUTURE BANDWIDTH REQUIREMENTS

Applications	Backbone Bandwith (terabits per second)
Online virtual reality	3,000 to 30,000
3-D holography/telepresence	30.000 to 70.000
Metacomputing	50.000 to 200.000
Web agents	50.000 to 200.000

1 terabit = 1 trillion bits

... for optical-fiber backbones—the most heavily used links—emerges in a study by consultant Adventis that shows that supply will overmatch demand. Yet new applications such as virtual reality and metacomputing could require huge increments in optical bandwidth above the few terabits per second currently needed to satisfy demand on U.S. communications backbones.

place, one critical part of the network requires conversion to electronics. About every 160 kilometers, a wavelength has to be converted back to an electronic signal to restore the shape and timing of individual pulses within the vast train of bits that occupy each lightwave.

Equipment suppliers also struggle mightily with electronics envy. Component suppliers such as JDS Uniphase labor on methods to build modules that combine lasers, fiber and gratings (which separate wavelengths). Building photonic integrated circuits remains difficult. Photons have no charge, as the negatively charged particles called electrons do, so there is no such thing as a charge-storage device, a photonic capacitor, that will store indefinitely the photons that represent zeros and ones. Moreover, it is difficult to build photonic circuitry as small as electronic integrated circuits, because the wavelength of infrared light used in fiber-optic lasers is about 1.5 microns, which places limits on how small you can make a component. Electronic circuits reached that dimension more than a decade ago.

The good news is that companies both small and large are now trying to solve problems such as signal restoration, and a pot of venture money exists to fund them. The field, which has taken on the same aura that genomics now holds and dot-coms once did, has become an exemplar of a new, hyperventilating mode of research. Tiny development houses proceed until they can furnish some proof that they can make good on their promises, and then they are bought out by a Nortel, Cisco or Lucent.

"It's a crazy world," says Alastair M. Glass, director of photonics at Lucent. "Anyone can go out with the dumbest ideas and get funding for them, and maybe they'll be bought for big bucks. And they've never made a product." Glass adds. "This has never happened in the past. Part of it is because companies need people, so they're buying the people. But other times they're buying the technology because they don't have it in the house, and sometimes they don't know what they're buying." From idea to development happens fast: a 1998 paper in *Science* about a "perfect mirror," a dielectric (insulating) material that reflects light at any angle with little loss of energy, inspired the founding of a company that wishes to create a hollow fiber whose circumference is lined with the reflector. The fibers may increase capacity 1,000-fold, one company official claims.

Will Anybody Come?

What can be done with all this bandwidth? Lucent estimates that if the growth of networks continues at its current pace, the world will have enough digital capacity by 2010 to give every man, woman and child, whether in San Jose or Sri Lanka, a 100-megabit-a-second connection. That's enough for dozens of video connections or several high-definition television programs. But does each !Kung tribesman in the Kalahari Desert really need to download multiple copies of *The Gods Must Be Crazy*?

Despite estimates of Internet traffic doubling every few months, some industry watchers are not so sure about infinite demand for infinite bandwidth. Adventis, a Boston-based consultancy, foresees only 15 to 20 percent of home Internet users obtaining broadband access—either cable modems or digital subscriber lines—by 2004. Moreover, storing frequently accessed Web pages on a server will reduce the burden on the network. In the U.S., according to the firm's estimate, nearly 40 percent of existing fiber capacity will go unused in 2004, whereas in Europe almost 65 percent will stay dormant. The notion of a capacity glut is by no means a consensus view, however.

In the end, terabit or petabit networking will probably emerge only once some as yet unforeseen use for the bandwidth reveals itself. Like the World Wide Web, originally a project to help particle physicists more easily share information, it may arrive on a tangent, not from a big media company's focused attempt to repackage networked virtual reality. Vinod Khosla, a venture capitalist with Kleiner Perkins Caufield & Byers, talks of the promise of projects that pool together computers that may be either side by side or distributed across the globe. Metacomputing can download Britney Spears and Fatboy Slim, or it can comb through radio telescope data in search of extraterrestrial life. Khosla sees immense benefit in using this model of networked computing for business, tying together machines to work on, say, the computational fluid dynamics of a 1,000-passenger jumbo jet.

So efforts to pick through the radio emissions from billions and billions of galaxies may yield useful clues about what on earth to do with a network pulsing a quadrillion bits a second. ■

FURTHER INFORMATION

See www.lightreading.com for a wealth of coverage on new technologies and on companies involved in optical networking.

Attachment 4

Verizon Tariff Pages Supporting
Affidavit Tables 1 - 4